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A monolithic rotating tool

BACKGROUND

Because of the ongoing miniaturisation, precision mechanics is becoming more and more important and this requires very high precision tools. High-speed cutting is one of the best ways to get a very high precision. Another advantage of very high-speed cutting is the fact that from a certain speed cutting forces and temperatures decrease as stated by Salomon in his Salomon curves. Another advantage of very high-speed cutting is that there is no need for using cutting fluids, which makes very high-speed cutting environmentally attractive. With environmental legislation becoming more and more severe high-speed cutting becomes more and more attractive.

The problem with high-speed cutting is that high-speed machines they are difficult to build. It is known that high-speed cutting technology is subject to the conflict of combining high processing/machining speed and high precision. This invention contributes to the construction of high speed and high precision rotating machines in general and cutting tools in particular.

A possible solution would be that a high speed and high precision cutting tool like a grinding wheel is made monolithic with its shaft, otherwise the high surface speed (which is the objective to be reached) will cause bursting of the rotating device/tool/blade owing to centrifugal forces. The problems with employing a monolithic rotating device/tool/blade are that, with the classical bearing systems, (i) replacing the rotating device, for instance the cutting tool, e.g. for the purpose of re-coating or revising in general, becomes very difficult; (ii) it would be very difficult to achieve good centricity of the axis of rotation, and (iii) Owing to the small (ball) bearing bores needed to achieve high speeds, the shaft has to be made small, which can lead to rotor dynamic instabilities. This makes it impossible to implement high-speed cutting with a monolithic cutting tool in an industrial environment where tool replacements are executed regularly. In general machinery wherein rotating device has to achieve a very high tip velocity, which is mainly a function of spindle speed and cutter size, are characterised in that they have above mentioned problems.

The present invention, however, overcomes these problems. With this new bearing system which uses the sides of the rotating device, e.g. the sides of a cutting tool as a counter-surface

for the bearings it is possible to use the advantages of a monolithic cutting tool on an industrial scale because it is easy to change the cutting tool. It was proven with a prototype of this invention that after exchanging the cutting tool the machine is as accurate as before.

SUMMARY OF THE INVENTION

This invention solves a fundamental problem of high-speed rotating devices. In order to have sufficient strength against bursting, the rotating device (e.g. cutting tool or milling wheel) has to be made monolithic with its shaft. Problems of the difficulty to provide effective bearing system to the rotating devise such that will ensure a stable, smooth and precise running and at the same time enable easy tool exchange has been overcome by a new bearing system. The invention provides an enhanced fluid film bearing system for high speed rotating tools, preferably cutting tools. The new bearing system allows higher precision and higher speeds combined with fast tool changing. The high precision and higher attainable speeds are the result of the fact that both journal and thrust bearing are placed close to the cutting tool which results in a very stiff construction and of the fact that the cutting tool is monolithic with its shaft. The fast tool changing is made possible by having one end of the bearing system removable. After this is done, the whole axis with the cutting tool can be removed. This is only possible because the sides of the cutting tool are used as a thrust bearing surfaces.

ILLUSTRATIVE EMBODIMENTS OF THE INVENTION

Brief description of the drawings

Fig. 1 is a cross-sectional view of an embodiment of a rotating device, for instance a rotating wheel or a cutting tool and preferably a grinding wheel. A possible application is high speed cutting, high speed grinding or High Speed Chipping (HSCh). Motor and rotating device, rotating wheel or grinding wheel are on different axes.

Fig. 2 is a detail of figure 1 illustrating the present invention.

Fig. 3 is a view of the monolithic tool-shaft illustrating the thrust bearing surfaces on the sides of the rotating device.

Fig. 4 is a cross-sectional view of an embodiment of a grinding wheel according to the present invention. The application is grinding. Motor and rotating device (e.g. grinding wheel or cutting tool) are on the same axis.

Description of the preferred embodiment

Figure 1 illustrates an embodiment of the invention, as it was build by the inventors. It is a high speed rotating device, preferably a grinding spindle or a cutting tool, with a motor on a separate axis. The rotating device (e.g. grinding wheel or cutting tool) **1** is monolithic with its shaft. Monolithic as defined in this application, does not mean that the rotating device (e.g. grinding wheel or cutting blade) and the shaft have necessarily to be made from a single material. The shaft-disc combination may indeed be fabricated from a combination of materials or composites, using a variety of techniques such as gluing, welding or shrink fitting. Therefore, the term monolithic in this application means that the shaft-disc combination is fabricated as one whole, in a suitable way so as to withstand the high stresses that are induced by centrifugal forces upon rotation, and that it is not practical to dismantle them after fabrication. The motor **2** is mounted on a separate axis. The two axes are joined with a coupling **3** that allows easy mounting and dismounting.

Figure 2 illustrates better the bearing system. In this embodiment it is a fluid bearing system, preferably a gas bearing system. However, it may be any fluid bearing of the hydrostatic and/or the hydrodynamic type, or it may be a magnetic bearing. The tool **1** , in this embodiment a grinding wheel, is supported by a fixed thrust and journal bearing **2** at one side and a removable thrust bearing **3** and journal bearing **4** at the other side of the cutting tool. The thrust bearings **2** and **3** use the sides, i.e. the faces, of the monolithic tool-shaft **1** as a bearing surface. The said sides or faces are flat in a preferred embodiment. But, it may have any shape of a surface of revolution, e.g. spherical (concave or convex) or conical. The thrust-and-journal bearing **2** **is** fixed in the housing **5.** The thrust bearing **3** and the journal bearing **4** are mounted in the cover **6** with bolts **9.** The cover **6** together with bearings **3** and **4** can be dismounted from the housing **5**. Then the monolithic wheel-shaft **1** can be dismounted. A new axis unit can be mounted and the cover **6** together with bearings **3** and **4** is mounted again. Guiding Dowel pins **7** ensure that the cover **6** and radial bearing **4** are replaced in the exact same radial position as before. The springs **8** position bearing **3** and set the thrust

bearing force by turning bolts **10**. The shaft is provided on each side with (tap) holes **11** for dynamic balancing.

With the construction presented above high precision bearing system are obtainable that can be easily dismounted for tool revision/up-hauling.

Figure 3 shows the monolithic shaft-tool combination of Figures 1 and 2 in detail. It demonstrates the journal and thrust bearing surfaces. The journal bearing surfaces are on both sides of the cutting tool, the thrust bearing surfaces are located on the faces of the cutting tool. It is also possible to combine the radial and thrust action of on both sides by making journal and thrust surfaces, on each side, one continuous surface, e.g. conical or spherical, or any other suitable surface of revolution.

Figure 4 shows another embodiment of the invention. In Fig. 4 the rotor of the motor **1** is mounted on the same axis **2** as the rotating device (e.g. cutting tool or grinding wheel). This makes a very compact construction possible and overcomes problems with the coupling. A special and very compact construction is obtained by embedding the rotor of the motor **1** inside the shaft of the tool, or in the tool (disc), and the stator 7 into the radial bearing or the thrust bearing respectively. It is important to note, in this regard, that the motor may be an electric A.C. or D.C. motor, or it can be a turbine or a viscous (laminar) motor that are driven by a fluid (i.e. liquid or gas). The bearings used are one fixed journal-and-thrust bearing combination **3** at the left side and at the right side one floating thrust bearing **4** combined with a journal bearing **5**. Bearings **4** and **5** are fixed in the cover **6.** The tool change is done in the same way as in the first embodiment.

Present invention involves an apparatus comprising a rotating tool or a rotating blade, preferably a milling wheel or a cutting tool that is monolithic with a shaft and a fluid film bearing system wherein the fluid film bearing system comprises two thrust bearings (axial bearings) at both coaxial surfaces of the blade and further comprising two journal bearings (radial bearings) positioned at the shaft. Such apparatus may be designed for balanced high-speed rotation. It may be a high-speed rotation apparatus, wherein said rotating tool is a disc. The rotating tool of this apparatus maybe a wheel, a disc, a rotor, a cutter, a blade or a drum.

Moreover the rotating tool may comprises magnets, an illumination source, or one or more sensor for high-speed detection or high-speed imaging.

In one embodiment of present invention the rotating tool is allowed to rotated at at least 10,000 rpm, preferably at 20,000 to 100,000 rpm and most preferably at 40,000 to 100,000 rpm. The apparatus may comprise a rotating tool that can be rotated at a surface speed of above between 1 km/min, preferably at a surface speed of above 10 km/min, and most preferably at a surface speed 10 km/min to 30 km/min.

The apparatus of present invention can comprise a high-speed cutting tool or a high-speed imaging tool. It can be an apparatus used for high-speed cutting. Or it can be an apparatus used for high-speed photography.

The apparatus of present invention can be designed in that during rotation better process stability is achieved than with conventional machinery or that during rotation better precision and process reliability is achieved than with conventional machinery.

In one embodiment a motor mounted on a different axis drives the apparatus. In another embodiment a motor mounted on the same axis drives the apparatus. In yet another embodiment the apparatus is driven by an electric motor and in yet another embodiment of present invention a turbine drives the apparatus.

A further embodiment of present invention comprises a high precision and high speed rotation device, comprising 1) a fluid (gas or liquid) bearing system which is a combined journal bearing and thrust bearing and 2) a blade which is monolithic with a shaft, wherein the thrust bearing uses the sides of the blade as a thrust bearing surfaces and journal bearings uses the shaft as journal bearing surface and wherein the blade is positioned between the two thrust bearings.

Yet another embodiment of present invention comprises a fluid bearing system for stabilising high speed rotation, characterised in that said bearing system is a combined journal and thrust bearing system, that the thrust bearing uses the sides of the rotating tool as a bearing surface, that the rotating tool being positioned between to two bearings and that the rotating tool is monolithic with the shaft. This bearing system may be used with a combination of self acting

and externally fed fluid film bearings, with magnetic bearings, with specially designed rolling element bearings. The bearings of this system may combine both bearing and motor function.